Quantifying the Co-benefits of Energy-Efficiency Programs: A Case Study of the Cement Industry in Shandong Province, China

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Executive Summary

China's cement industry accounted for more than half of the world's total cement production in 2010. The cement industry is one of the most energy-intensive and highest carbon dioxide (CO_2)-emitting industries and one of the key industrial contributors to air pollution in China. For example, it is the largest source of particulate matter (PM) emissions in China, accounting for 40 percent of industrial PM emissions and 27 percent of total national PM emissions. Although specific regulations and policies are needed to reduce the pollutant emissions from the cement industry, air pollution can also be reduced as a co-benefit of energy efficiency and climate-change mitigation policies and programs. Quantifying and accounting for these co-benefits when evaluating energy efficiency and climate-change mitigation programs reveals benefits beyond the programs' energy and global warming impacts and adds to their cost effectiveness.

In this study, we quantify the co-benefits of PM_{10} and sulfur dioxide (SO_2) emissions reductions that result from energy-saving measures in China's cement industry. We use a modified form of the cost of conserved energy (CCE) equation to incorporate the value of these co-benefits:

$$CCE_{co\text{-}ben} = \frac{(\text{annualized capital cost + annual change in operations\&maintenance costs - annual co-benefits})}{\text{annual energy savings}} \qquad \textbf{(Equation ES-1)}$$

The annualized capital cost can be calculated as follows:

$$\text{Annualized capital cost} = \text{Capital Cost}*(d/\ (1-(1+d)^{-n}) \qquad \textbf{(Equation ES-2)}$$

where:
d = discount rate (assumed 30 percent in this study)
n = lifetime of the energy-efficiency measure

We used the following methodology to calculate CCE with co-benefits ($CCE_{co\text{-}ben}$):

1. We established the year 2008 as the base year for energy, materials use, and production in 16 representative cement plants in Shandong Province. We also used 2008 data when modeling air quality and health impacts, as described below.

2. We compiled a list of 34 commercially available technologies Out of the 34 measures, 29 are applicable to the cement plants in our study, 23 are electricity-saving measures, and 6 are fuel-saving measures. To quantify the air pollution emissions (PM and SO_2) reductions associated with the electricity-saving measures, we used relevant average emission factors for the electricity grid. We did not conduct the air quality modeling or analyze health impacts of the electricity-saving measures because the air pollution from electricity generation is emitted by power plants that are dispersed around the region which is beyond the scope of this study, and our goal in this study is in the air pollution effects of the cement plants themselves. Therefore, in quantifying co-benefits to be included in the CCE calculation, we focused only on the six fuel-saving measures because those measures reduce air pollution at the cement plant site.

3. We assessed the potential application of the energy-efficiency technologies and measures in the 16 Shandong cement plants based on information collected from the plants.

4. We calculated energy savings and CO_2 and air pollutant (PM_{10} and SO_2) emissions reductions for each technology at each cement plant.

5. We modeled air quality for PM_{10} and SO_2 separately, to obtain emissions concentrations for the base and efficiency cases. We performed this modeling only for the six fuel-saving measures. (Section 3.4. describes the modeling in detail).

6. Using the emissions concentration data obtained in the previous step, we calculated the health benefits of the fuel-saving measures using the concentration-response function. (Section 3.5 explains the details of this calculation).

7. Using the monetary value of the co-benefits from the PM_{10} and SO_2 emissions reductions associated with each fuel-saving measure, we calculated the CCE with co-benefits included (see Equation ES-2).

The results show that more than 41 percent of the PM and SO_2 emissions reduction potential of the electricity-saving measures is cost effective even without taking into account the co-benefits for the electricity-saving measures for the reason explained above. (Figure ES-1). The results also show that including health benefits from PM_{10} and SO_2 emissions reductions reduces the CCE of the fuel-saving measures (Table ES-1).

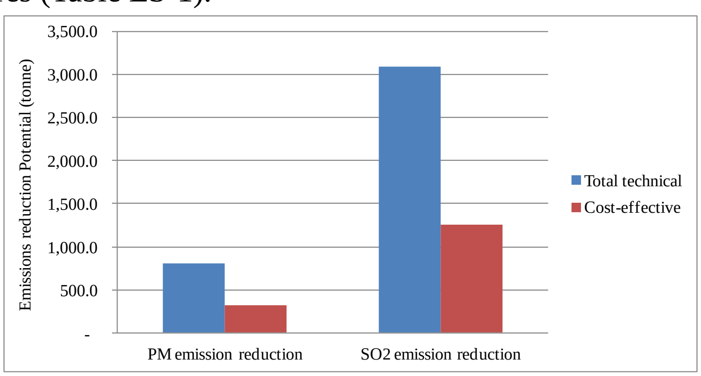

Figure ES-1. Cost-effective and total technical potential in 2008 of PM and SO_2 emissions reductions resulting from electricity-saving measures in 16 cement plants in Shandong Province

Table ES-1. PM_{10} and SO_2 emissions reduction potential and CCE and $CCE_{co\text{-}ben}$ of fuel-saving measures in 2008 for 16 cement plants in Shandong Province

CCE Rank	Efficiency Measure [b]	PM_{10} Emission Reduction (ton PM_{10})	SO_2 Emission Reduction (ton SO_2)	CCE (RMB/GJ-saved)*	$CCE_{co\text{-}ben}$ (RMB/GJ-saved)	Difference (%)
1	Blended cement (additives: fly ash, pozzolans, and blast furnace slag) [a]	2,560	248	0.72	0.25	-65%
2	Limestone Portland cement [a]	850	13	0.76	0.16	-80%
3	Kiln shell heat loss reduction (Improved refractories)	-	270	1.98	1.89	-5%
4	Use of alternative fuels	-	215	3.78	3.76	-1%
5	Optimize heat recovery/upgrade clinker cooler [a]	-	28	4.71	4.56	-3%
6	Energy management and process control systems in clinker making	-	202	12.60	12.4	-1%

*RMB/GJ = Renminbi per gigajoule

[a] For this measure, primary energy savings were used to calculate CCE and $CCE_{co\text{-}ben}$ based on both the electricity and fuel savings. However, because fuel savings have a larger share than electricity savings, this measure is included with the fuel-saving measures.

[b] Brief descriptions of the fuel-saving measures are provided in Appendix A.5.

The two measures that entail changing products (production of blended cement and limestone Portland cement) showed the largest reduction in CCE when co-benefits were included because these measures can reduce both PM_{10} and SO_2 emissions, whereas the other fuel-saving measures do not reduce PM_{10}. This shows the importance of the PM_{10} emissions reduction from the cement industry and how significant the benefits are from reducing this pollutant. The sensitivity analysis showed that the CCE with co-benefits included ($CCE_{co\text{-}ben}$) has an inverse relation with concentration-response coefficients and the unit value of the health outcomes (disease/death) and a direct relation with wind speed.

The report also describes uncertainties relating to the scope, air quality modeling, health benefits assessment, and CCE calculation in this study and identifies the following areas of future research: incorporating other emissions, particularly $PM_{2.5}$, in the analysis; performing similar co-benefits assessments of other industries in China; and studying the policy implications of co-benefits assessment, particularly in developing countries.

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